Nigerian Journal of Engineering
Faculty of Engineering
Ahmadu Bello University
Samaru - Zaria, Nigeria

Vol. 27, No. 1, April 2020
ISSN: 0794 - 4756

COMPARATIVE INVESTIGATION ON THE IMPACT OF CHEMICAL AND BIOFERTILIZERS ON SOME SOIL PROPERTIES

A. Bello*[1], D. B. Adie[2], U. A. Abubakar[2], A. Giwa[3], O. A. Adetunji[1] and Y. Adamu[4]

[1]National Biotechnology Development Agency, FCT Abuja/BIODEC Ilorin.
[2]Department of Water Resources and Environmental Engineering, Ahmadu Bello University, Zaria, Nigeria.
[3]Department of Polymer and Textile Engineering, Ahmadu Bello University, Zaria, Nigeria.
[4]Department of Chemical Engineering, Ahmadu Bello University, Zaria, Nigeria.
***Corresponding Author's Email: babdallah903@gmail.com**

ABSTRACT
Persistent and indiscriminate uses of chemical fertilizer for crops growth had numerous negative effects on the soil over the years. Biofertilizer, which has been reported to be more effective than chemical fertilizer in terms of healthy crop growth without destroying soil ecology lacks awareness. This article investigated the comparisons studies between the chemical and biofertilizers effects on soil properties. The aim was actualized by setting up three replicates (biofertilizer, chemical fertilizer and control) with fifteen (15) numbers of pots in each case. Each pot contained 2000 g of sand with 2-seeds planted in each case. The control replicate was given zero fertilizer treatment. Concentrations of fertilizers were varied on biofertilizer and chemical fertilizer replicates using design expert tool. The physio-chemical properties, soil pH and water holding capacity of the soil were analyzed before planting and afterwards for all the three replicates. The results showed that, the effects of biofertilizer and chemical fertilizer on soil pH are insignificant because, their percentage error differences when compared to the base soil pH are 1.5% and 0% respectively. The carbon to nitrogen ratio in the biofertilizer soil replicate increased from 3.38 to 9.93 after harvest, but decreased to 0.45 in chemical fertilizer soil replicate. The water holding capacity of the biofertilizer soil replicate also increased from 3.26% to 5.55%, while it was reduced to 3.12% in chemical fertilizer replicate. This result shows that, there is 41.26% water holding capacity increase in the biofertilizer soil replicate, compared to the chemical fertilizer soil replicate with 4.29% water loss. It can therefore be concluded that, chemical fertilizer has an adverse effect on soil properties, as evidence from depletion of water holding capacity and organic carbon observed from chemical fertilizer treatment.
Keywords: *Biofertilizer, chemical fertilizer, soil properties, comparison.*

INTRODUCTION
Biofertilizers are preparation of efficient strains of microorganisms rich in living cells for crop nutrients uptake, through their interactions in the rhizosphere (Faludin, 2009; Anil *et al*., 2016; Andressa *et al*., 2017). Chemical fertilizers are obtained from synthetic origins which are generally inorganic substances in nature (Neni *et al*., 2004; Khanom, 2008; Staff, 2018). Chemical fertilizer increases the soil acidity, which enhances reduction in the beneficial soil microorganism populations. Biofertilizer however increases soil water retention capacity, improve organic matter, enhances the soil microorganism to strive within the soil and mobilize vital growth nutrients for plant use (Neni *et al*., 2004; Ibrahim, *et al*., 2013).

It has been established that both chemical and biofertilizers are important agricultural tools that help farmers to enhance their farm produce (Shah and Rajendra, 2012; Francis and Berhanu, 2016; Ivana *et al*., 2016). As reported in the work of Bruand *et al*. 2005; Adekunle *et al*. 2017, fertilizers have been used over the years in agricultural practices to improve the healthy growth of crops, as evidence from their significant roles in increasing agriculture production across the world. The general awareness and availability of chemical fertilizer made it farmer's first choice over its biofertilizer counterpart (Kamla and Uttar, 2009; Niño *et al*., 2012; Meenakshi, 2016). The negative effects on soil and natural environment afterwards by chemical fertilizers is a big concern (Shah and Rajendra, 2012; Tinatin *et al*., 2015; Adekunle *et al*., 2017). These effects often prevent the availability of vital nutrients that plants need for healthy growth (Shah and Rajendra, 2012; Vikas *et al*., 2014; Mohamed *et al*., 2018).

These effects have gradually made the natural soil and its growth nutrients vulnerable over the years, and its continuous utilization will be a huge detriment to the future farming activities. Based on these, researchers are now focusing on different technologies for alternative crop growing supports of which biofertilizer application is not left out. Therefore, the choice of biofertilizer in this work in comparison with its chemical fertilizer impacts on some soil properties. This article is therefore aimed at comparison investigation on the impact of chemical and biofertilizers on soil.

MATERIALS AND METHODS
Sourcing of Materials Used
The soil used was imported from Crop Protection Departmental farm garden, Ahmadu Bello University, Zaria. The plant pots used were purchased from Sabon-gari market, the maize seeds used, identified as *samaize 37* specie were obtained from Plant Science Department, Ahmadu Bello University, Zaria. The NPK (chemical fertilizer) used was obtained commercially from El-Hayyat fertilizer Company, Kano Road, Zaria, while the biofertilizer counterpart was produced.

Soil analysis

British Standard (BS 5930) standard procedure was adopted to identify the type of soil used in this work. The pore size/texture of the soil was determined using stack of sieve size ranges of (0.71 mm, 0.425 mm, 0.36 mm, 0.212 mm and 0.075 mm). It was classified into (sand with 89.8 wt %, 7.9 wt % of silt and 2.3 wt % clay) using soil texture triangle as shown in Plate I.

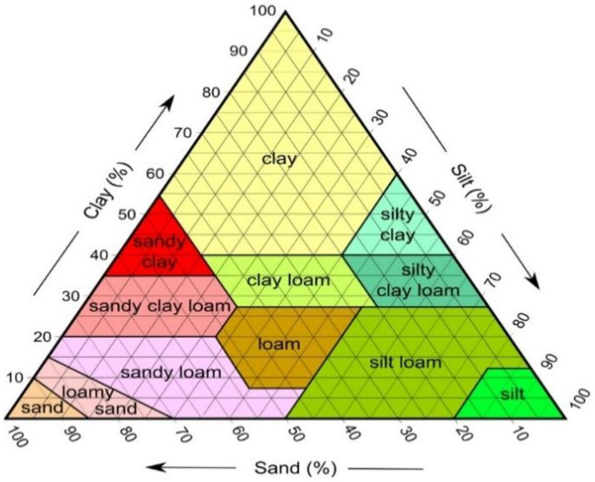

Plate I: Soil texture triangle for type of soil classifications
Source: (Marco and Markus, (1999); Ruben *et al*., 2015)

Based on these classifications and the percentage weight of sand contained in the soil, it was therefore identified as sandy soil.

Design of experiment

Impacts of biofertilizer and chemical fertilizer on some soil properties were investigated by considering three variable parameters such as fertilizers concentrations, sand concentration and quantity of maize seeds, using Design of Experiment (DOE) as software aid. These independent variables were investigated on the pH and Water Holding Capacity (WHC) of the soil, in which Response Surface Methodology (RSM) technique embedded in the DOE package, was adopted. Table 1, 3 and 3 showed the boundary conditions of the independent variables experimental design for biofertilizer, chemical fertilizer and control treatments respectively.

Table 1: Design of experiment independent input variables for biofertilizer treatmet

Factor	Unit	Low value	High value
Biofertilizer (A)	g	10	60
Maize seed (B)	g	2.00	2.00
Quantity of sand (C)	g	2000	2000

Table 2: Design of experiment independent input variables for chemical fertilizer treatment

Factor	Unit	Low value	High value
Chemical fertilizer (A)	g	10	60
Maize seed (B)	g	2.00	2.00
Quantity of sand (C)	g	2000	2000

Table 3: Design of experiment independent input variables for control

Factor	Unit	Low value	High value
Fertilizer (A)	g	0.00	0.00
Maize seed (B)	g	2.00	2.00
Quantity of sand (C)	g	2000	2000

As shown in Table (1-3), the number of seeds per pot and the quantity of sand per pot were kept constant from the input experimental design; however the concentrations of fertilizers were varied between 10 g and 60 g within the design boundaries, with the exceptions of control maize plant replicate with zero fertilizers concentration treatment. The number of experimental output runs were fifteen (15) in each treatment, Table 4-6 present the details.

Table 4: Design summary of the biofertilizer treatment

Runs	Biofertilizer	Maize seed	Quantity of sand	pH	Water holding capacity
1	10	2.00	2000	,,	,,
2	60	2.00	2000	,,	,,
3	10	2.00	2000	,,	,,
4	60	2.00	2000	,,	,,
5	10	2.00	2000	,,	,,
6	60	2.00	2000	,,	,,
7	10	2.00	2000	,,	,,
8	60	2.00	2000	,,	,,
9	7.04	2.00	2000	,,	,,
10	77.04	2.00	2000	,,	,,
11	35	2.00	2000	,,	,,
12	35	2.00	2000	,,	,,
13	35	2.00	2000	,,	,,
14	35	2.00	2000	,,	,,
15	35	2.00	2000	,,	,,

Table 5: Design summary of the chemical fertilizer treatment

Runs	Chemical fertilizer	Maize seed	Quantity of sand	pH	Water holding capacity
1	10	2.00	2000	,,	,,
2	60	2.00	2000	,,	,,
3	10	2.00	2000	,,	,,
4	60	2.00	2000	,,	,,
5	10	2.00	2000	,,	,,
6	60	2.00	2000	,,	,,
7	10	2.00	2000	,,	,,
8	60	2.00	2000	,,	,,
9	7.04	2.00	2000	,,	,,
10	77.04	2.00	2000	,,	,,
11	35	2.00	2000	,,	,,
12	35	2.00	2000	,,	,,
13	35	2.00	2000	,,	,,
14	35	2.00	2000	,,	,,
15	35	2.00	2000	,,	,,

Table 6: Design summary of the control

Runs	Chemical fertilizer	Maize seed	Quantity of sand	pH	Water holding capacity
1	0.00	2.00	2000	,,	,,
2	0.00	2.00	2000	,,	,,
3	0.00	2.00	2000	,,	,,
4	0.00	2.00	2000	,,	,,
5	0.00	2.00	2000	,,	,,
6	0.00	2.00	2000	,,	,,
7	0.00	2.00	2000	,,	,,
8	0.00	2.00	2000	,,	,,
9	0.00	2.00	2000	,,	,,
10	0.00	2.00	2000	,,	,,
11	0.00	2.00	2000	,,	,,
12	0.00	2.00	2000	,,	,,
13	0.00	2.00	2000	,,	,,
14	0.00	2.00	2000	,,	,,
15	0.00	2.00	2000	,,	,,

PHYSICO-CHEMICAL ANALYSIS

pH Analysis of the Soil Before and Afterwards

Shoemaker-McLean-Pratt standard technique was adopted for the soil pH determination. This was done by calibrating the pH meter over pH range of (1-14) using standard buffer solution. 5 g of sieved air-dried unused soil sample was scooped into a paper cup, after which 5 ml of distilled water was added to the sample. The solution was stirred continuously for 15 secs and allowed to stand for 30 mins. The pH meter electrode tip was placed in the solution and the value was recorded. This was repeated five times the average reading was recorded. The same procedure was repeated after the application of fertilizers/post-harvest for each run and their average values were recorded in each case.

Soil texture and water holding capacity determination

The water holding capacity (WHC) of the soil was determined using ASTM D2487-11 standard. This was done by selecting a bund around (5 m x 5 m) plot in Crop Protection Departmental farm garden, where the sand used was imported. The area selected was filled with 20 liters of water to sufficiently saturate the soil. The selected area was then covered with polyethylene sheet to check evaporation. Soil sample was taken from the centre point of the plot after 24 hours of saturation to determine the moisture content on a daily basis until there is no significant change in the values of successive days. The numerical values of the WHC were determined by computing the weight of empty moisture container (X), weight of moisture container plus moisture soil (Y) and wight of moisture container plus oven dried soil (Z). This was repeated after harvest for each run and the average values in each case were presented.

Moisture content in soil = Y – Z

Weight of oven dried soil = Z – X

Percentage of moisture content $= x = \frac{Y-Z}{Z-X}\, x\, 100$ (1)

PROXIMATE ANALYSIS

Soil Nutrients Analysis Before and Afterwards

Potassium, phosphorus and nitrogen were the three soil nutrients selected as proximate analysis of the soil before and after the application of fertilizers.

Potassium

Olsen's method was adopted in determining the available potassium in the soil before planting and afterwards. This was done by extracting the amount of potassium present in solution with neutral ammonium acetate of 1 molarity. The available potassium from in the soil was then estimated with the aid of flame photometer.

Phosphorus

The soil used is in acidic medium. Based on this, *Bray's* standard method was suitable for the analysis; therefore it was adopted in determining the available phosphorus in the soil. The technique involved scooping 1 g of air-dried soil into 10 ml of extractant solution, which was shake for 5 mins. The amount of phosphorus extracted was determined by measuring the intensity of blue color developed in the filtrate when it was treated with ascorbic acid reagent. This was done for the unused soil and the procedure was repeated on the soil after post-harvest, in which the average values were recorded.

Nitrogen

Kjeldahl digestion method was adopted in determining the amount of nitrogen present in the soil before and after fertilizers application. 1 g of the soil sample was weighed and placed in 250 ml capacity of conical flask. 0.7 g of copper sulphate was then added alongside 1.5 g of K_2SO_4 and 30 ml of H_2SO_4. The solution was heat gently until frothing ceases. Afterwards, the digestion process was continued for 30 mins, after which the flask containing the solution was removed from the heating source and allowed to be cooled. 50 ml of water was then added before transferring to a distilling flask containing 20 ml of standard acid (0.1 M HCl). Then, excess acid from the distillate was titrated with 0.1 M NaOH, and the amount of nitrogen content present was estimated.

RESULTS AND DISCUSSION

Physio-Chemical Analysis of the Soil

Impacts of the fertilizer on pH and water holding capacity on the soil investigated are presented in this section. Table 7 presents results of the responses (pH and water holding capacity) studied from the independent variables (fertilizers concentrations, soil concentrations and quantities of maize seed per pot) interactions for biofertilizer and chemical fertilizer respectively.

Table 7: Response from the experimental investigation of the independent variables

Runs	Fertilizer conc.	Maize seed	Quantity of sand	pH	WHC
Biofertilizer treatment					
1	10	2.00	2000	6.7	5.55
2	60	2.00	2000	6.65	5.56
3	10	2.00	2000	6.6	5.55
4	60	2.00	2000	6.59	5.54
5	10	2.00	2000	6.71	5.53
6	60	2.00	2000	6.55	5.55
7	10	2.00	2000	6.76	5.57
8	60	2.00	2000	6.57	5.56
9	7.04	2.00	2000	6.9	5.54
10	77.04	2.00	2000	6.7	5.54
11	35	2.00	2000	6.6	5.55
12	35	2.00	2000	6.6	5.56
13	35	2.00	2000	6.5	5.55
14	35	2.00	2000	6.6	5.57
15	35	2.00	2000	6.8	5.55
Average				6.7	5.55
Chemical fertilizer treatment					
1	10	2.00	2000	6.53	3.12
2	60	2.00	2000	6.62	3.15
3	10	2.00	2000	6.53	3.14
4	60	2.00	2000	6.54	3.12
5	10	2.00	2000	6.55	3.15
6	60	2.00	2000	6.58	3.11
7	10	2.00	2000	6.58	3.00
8	60	2.00	2000	6.56	3.16
9	7.04	2.00	2000	6.64	3.12
10	77.04	2.00	2000	6.8	3.13
11	35	2.00	2000	6.6	3.16
12	35	2.00	2000	6.6	3.22
13	35	2.00	2000	6.5	3.22
14	35	2.00	2000	6.4	3.12
15	35	2.00	2000	6.7	3.12
Average				6.6	3.14

The average pH values presented in Table 7 showed that, there was no significant negative effect impacted on the soil by the two fertilizer's impacts in terms of pH. This is evident from the average post-harvest pH values of 6.7, 6.6 and 6.5 recorded in biofertilizer, chemical fertilizer and control treatments respectively. It was therefore, observed that both the pH values obtained before planting and afterwards are within the range of (5.5 to 7.5) specifications suitable for plant growth as reported by William, (2000); Hartman *et al*. (2002); Razaullah *et al*. (2002); Roy *et al*. (2006); Eva and Farmington (2009); Igboro, (2011); Ayesha *et al*. (2016); Staff, (2018). The insignificant difference observed on the soil pH was further proved statistically using the analysis of variance (ANOVA) as shown in Table 8.

Table 8: Analysis of variance for the fertilizers impact on soil pH

Factors	Mean square	F-value	Prob > F	Model Remark	R^2	Adj. R^2	Adq. precision	Error (%)
Biofertilizer treatment								
Model	0.15	27.88	0.0009	Significant	0.9805	0.9801	18.190	0.041
A	0.041	66.16	0.0005					
B	0.00059	0.96	0.3717					
C	0.00349	5.65	0.0633					
Chemical fertilizer treatment								
Model	0.11	5.87	0.0329	Significant	0.9135	0.9133	9.077	0.022
A	0.011	5.27	0.0702					
B	0.00036	0.18	0.6893					
C	0.002	0.51	0.5063					

As it can be seen from Table 8, the pH models for both treatments are significant as their prob > F of 0.0009 and 0.0329 are less than 0.05. The R^2 of 0.9801 and 0.9135 in both cases are also desirable because they are close to 1. Their adequate precision also proved that; the model is adequate enough to describe the interactions. The percentage error differences of 0.041 and 0.022 for biofertilizer and chemical fertilizer respectively showed that, the fertilizers effects were statistically insignificant.

Water holding capacity of the soil before fertilizer application and afterwards

The average water retained by biofertilizer and chemical fertilizer soil treatments after harvest were 5.55% and 3.14% respectively (see Table 9), which are below standard requirement of 15% for sandy soil as reported by Thomas, (2002); Faludin, (2009); Mohammad *et al*. (2015) for an effective plant growth. The improvement in water holding capacity from the baseline value of 3.26% to 5.55% in biofertilizer soil replicate translated to 41.26% increased after harvest compared to the chemical fertilizer soil replicate which was reduced from 3.26% to 3.14%, amounted to 4.29% less water retained than the baseline. The water retention capacity improvement observed in biofertilizer soil replicate is due to the microbial activities in recycling the organic matter present, increasing the soil pore spaces and forming a cohesive force to hold soil-water within the soil to create favorable conditions for nutrient ions movement to the root when compared with chemical fertilizer soil replicate with poor organic matter, as a result of fertilizer-soil leaching effects. Table 9 shows the statistical analysis of variance done on the water holding capacity for both treatments.

As depicted in the table, the water holding capacity of biofertilizer treatment is significant as its Prob > F value of 0.0104 is less than 0.05, when compared to the chemical treatment with 0.8291. This indicates that, chemical fertilizer has negative effect on the soil water holding capacity as evidence from its R^2 of 0.4723 and negative R^2-adjusted value, when compared with biofertilizer treatment with R^2 value of 0.9472. This proved that, the observations from the experimental response data are consistent with the statistical records.

Table 9: Water holding capacity of the soil in for biofertilizer and chemical fertilizer treatment

Factors	Mean square	F-value	Prob > F	Model Remark	R^2	Adj. R^2	Adq. precision	Error (%)
Biofertilizer treatment								
Model	0.0017	9.97	0.0104	Significant	0.9472	0.8522	10.433	10
A	0.000073	0.39	0.5591					
B	0.000161	8.57	0.0327					
C	0.000139	7.45	0.0413					
Chemical fertilizer treatment								
Model	0.017	0.50	0.8291	Not significant	0.4723	-0.4775	2.423	198.9
A	0.0.0158	0.41	0.5485					
B	0.00006	0.0016	0.9698					
C	0.0057	1.48	0.2774					

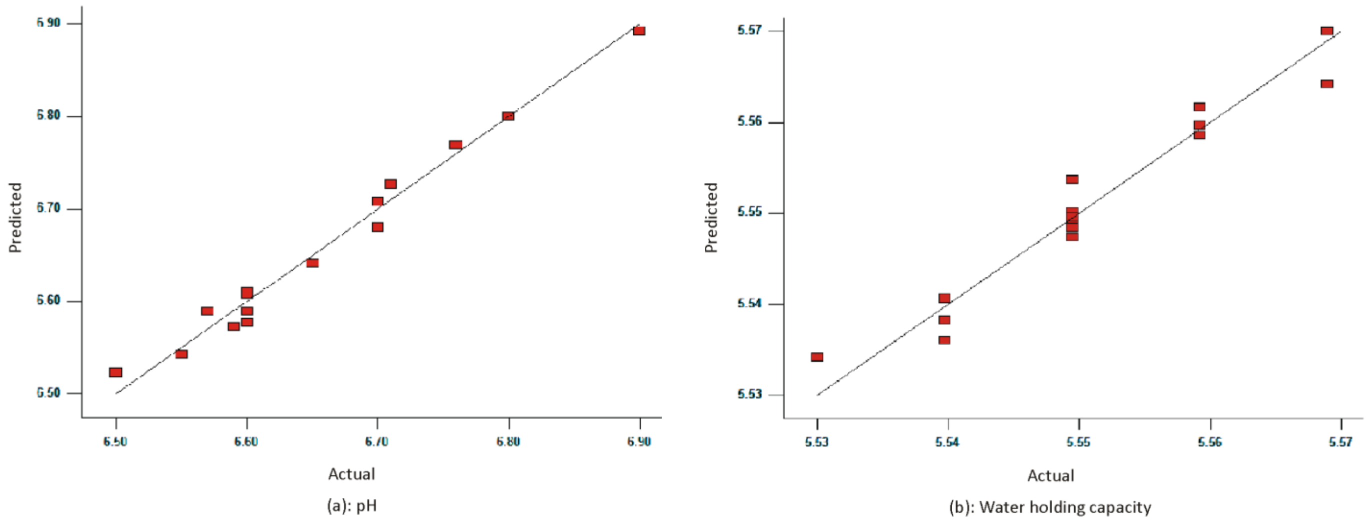

Figure 1: Relationship between predicted and actual response in biofertilizer treatment

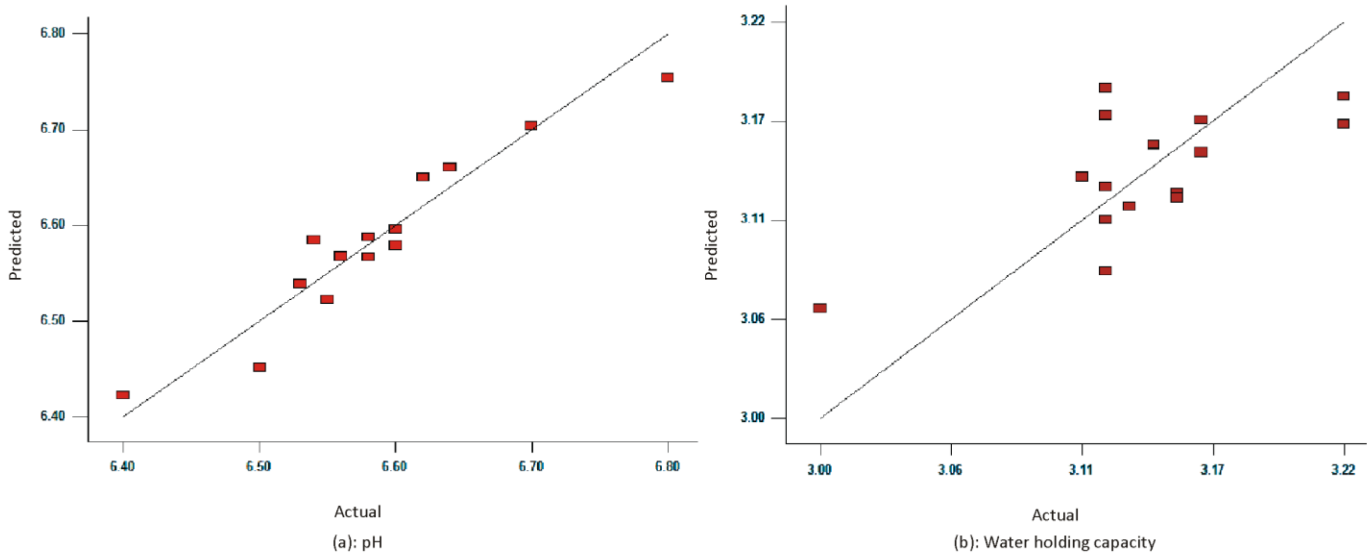

Figure 2: Relationship between predicted and actual response in chemical fertilizer treatment

The data points in Figure 1 (a and b) distributed evenly along the regression line without outlier as shown. This indicates a good agreement between the predicted and experimental independent variable interactions as proved by their R^2-values. As also shown in Figure 2a, the pH data points were distributed along the regression line unlike in Figure 2b, where there are outlier points of clumps along the regression line. The predicted and experimental water holding capacity relationships shown in Figure 2b further confirmed the significant effect chemical fertilizer has on water holding capacity of soil.

Proximate analysis of the soil

Roy *et al*. (2006) and Itelima *et al*. (2018) reported that, the mean average concentration of nitrogen, phosphorus and potassium required in the soil for healthy plant growth are 1.5%, (0.1-0.4) % and (1-5) % respectively. As shown in Table 10, the values recorded for phosphorus and potassium were lower than 1.5%, (0.1-0.4) % and (1-5) % respectively as reported by Roy *et al*. (2006) and Itelima *et al*. (2018). However, higher than the initial concentrations in both treatments, except C: N that reduced in chemical fertilizer treatment as presented in Table 10.

Table 10: Primary soil nutrients analysis of the treatments before planting and afterwards

Parameters	Composition before planting (%)	Biofertilizer's soil replicate compositions after harvest (%)	Chemical fertilizer's soil replicate compositions after harvest (%)	Control soil replicate compositions after harvest (%)
Nitrogen (N)	0.08	1.5	0.77	0.074
Phosphorus (P)	L.D	0.032	0.025	L.D
Potassium (K)	0.014	0.037	0.030	0.00402
Organic Carbon (C)	0.27	14.89	0.35	0.27
C: N	3.38	9.93	0.45	3.65

LD: Low detection

It was observed that, there was loss of available nutrients through leaching, as the chemical fertilizer used in this replicate originally contained 20% (N), 10% (P) and 10% (K). On the other hand, biofertilizer's initial constituents were 0.28% (N), 0.0099 % (P) and 0.048% (K). The post-harvest soil nutrients as shown in the Table 10, suggest that, made them available to the plant and enriched the soil for plant growth. The post-harvest soil analysis done on the control replicate showed that, there were reduction in the nitrogen and potassium contents from (0.08 to 0.074) % and (0.014 to 0.00402) % respectively. This can be justified because, there was no fertilizer treatment given to this replicate for its plants support. It therefore be said that, only biofertilizer's soil replicate meets the requirement in terms of nitrogen soil nutrient concentration after harvest.

Organic carbon and nitrogen nutrients relationships

The soil fertility and its productivity are highly dependent on soil organic carbon (Roy *et al*., 2006). This is because; soils with appreciable amount of organic carbon or matter improve the soil structure, which is a function of high-water holding capacity in the soil. Therefore, Table 10 shows the amount of organic carbon to nitrogen ratio present in the soil before and after harvest for the three replicates. The organic carbon increased from 0.27% to 14.89% and 0.35% for biofertilizer and chemical fertilizer respectively, but remained the same as 0.27% in the control soil after harvest. These amounted to the carbon to nitrogen ratio of 9.93, 0.45 and 3.65 respectively. This indicated that, biofertilizer soil replicates has better (C: N), from the initial value of 3.38, compared with the other two soil replicates after harvest.

CONCLUSIONS

It is concluded from the investigation carried out that, both biofertilizer and chemical fertilizer did not significantly change the soil pH as evident from error difference of 0.04 % and 0.02 % respectively. However, chemical fertilizer has negative effect on the water holding capacity of the soil as its water retention capacity was observed to reduced, compared with biofertilizer impact whose water holding capacity increased from the initial state. Biofertilizer was observed to have improve the soil nutrients conditions, as an increased in carbon (C) to nitrogen (N) ratio from 3.38 to 9.93 was observed after harvest, when compared to the fertilizer soil treatment whose C: N value decreased from 3.38 to 0.45. It can therefore be concluded from the overall findings that; chemical fertilizer has an adverse effect on the soil compared with biofertilizer.

REFERENCES

Adekunle, R., Rasheed, A. and Ashira, R. (2017). Soil fertility challenges and Bio-fertiliser as a viable alternative for increasing smallholder farmer crop productivity in sub-Saharan Africa. 3(1400933). *Cogent Food and Agriculture*. doi.org/10.1080/23311932.2017.1400933. pg. 2 of 26 and 4 4 of 26.

Andressa, C. N., Camila, N. B., Rafaela, D. O., Leonardo, M. P., Gonçalves, D. C. and Eliane H, (2017). Effect of biofertilizer obtained by anaerobic digestion of cassava effluent on the development of crambe plants. *Revista Brasileira de Engenharia Agrícola e Ambiental*. v.21, n.10. DOI: http://dx.doi.org/10.1590/1807-1929/agriambi.2 (10).

Anil, K. S., Singh, A. P., Naveen, G., Abhishekh, S. and Arun, K. (2016). A review on blue green algae as biofertilizer (site characteristics, location and boundaries of Vindhya. basin, geology of Rewa, physiography, climatology). I*nternational Journal of Botany Studies*. 1(1). ISSN: 2455-541X. Pg. 5 - 6.

Ayesha, A., Jalil, A. and Shahid, R. (2016). Effect of pH and moisture content on composting of municipal solid waste. *International Journal of Scientific and Research Publications*. 6 (5). Pg. 34 and 36.

Bruand, A., Hartman, C. and Lesturgez, G. (2005). Physical properties of tropical sandy soils: A large range of behaviours. Soil Science of America Journal. Pg. 64.

Eva, M. C. and Farmington, N. H. (2009). Best management practices (BMPs) for incorporating food residuals into existing yard waste composting operations. *U. S. Composting Council,* Bethesa.

Faludin, M. (2009). Formula effectiveness of biofertilizer in stimulating nutrient uptake, production and quality of corn yield and upland rice (In Indonesian). *A Thesis in Plant Biology. Postgraduate Program*. IPB, Bogor.

Francis, A. and Berhanu, A. (2016). Potential Use of Cyanobacterial Bio-fertilizer on Growth of Tomato Yield Components and Nutritional Quality on Grown Soils Contrasting pH. *Journal of Biology, Agriculture and Healthcare*. Vol.6, No.17.

Hartman, L., Atieno, M., Brau, L. and Lesueur, D. (2002). Microbial quality of commercial inoculants to increase BNF and nutrient use efficiency. In F. J. de Bruijn (Ed.), *Biological Nitrogen Fixation* (pp. 1031 - 1040). Hoboken, NJ: Wiley. https://doi.org/10.1002/9781119053095.

Ibrahim, M. H., Jaafar, Z. E. H., Karimi, E. and Ghasemzadeh, A. (2013). Impact of oorganic and iinorganic Fertilizers Application on the Phytochemical and Antioxidant Activity of Kacip Fatimah (*Labisia pumila* Benth). *Molecules* 18(2004), 10974. doi:10.3390/molecules180910973.

Igboro, S. B. (2011). Production of biogas and compost from cow dung in Zaria, Nigeria. A PhD. Thesis, Department of Water Resources and Environmental Engineering, Ahmadu Bello University, Zaria.

Itelima, J. U., Bang, W. J., Sila, M. D., Onyimba, I. A. and Egbere, O. J. (2018). A review: Biofertilizer - A key player in enhancing soil fertility and crop productivity. *Microbiol Biotechnol Rep*. 2 (1). 3 - 4.

Ivana, T., Zorica, G. and Adriana, R. (2016). Effects of the application of biofertilizers on the microflora and yield of lettuce (*Lactuca sativa* L.). *Acta Agriculturae Serbica, Vol. XXI, 42*. 91 - 93.

Kamla, N. N. and Uttar, P. (2009). Biofertilizers and organic fertilizers in fertilizer control order. National Centre for Organic Farming. Department of Agriculture and Cooperation, Ministry of Agriculture, Government of India. Pg. 18 - 19.

Khanom, S., Saha, B. K., Islam, M. T. and Chowdhury, M. A. H. (2008). Influence of organic and inorganic fertilizers on the growth, leaf yield, chlorophyll and protein contents of stevia grown in different soil types. *Progress Agric.* Doi: 10.3329/pa.v19i1.16986. 19 (1). 2 and 7.

Marco, B., Gaylon, S. C. and Markus, F. (1999). Characterization of particle-size distribution soil with a Fragmaton model. *Soil Science Social*.

Meenakshi, S. (2016). Potential of Biofertilizers to Replace Chemical Fertilizers. *International Advanced Research Journal in Science, Engineering and Technology*. 3 (5). DOI 10.17148/IARJSET.2016.3534. Pg. 163 and 165.

Mohammad, B., Javadi N., Halimi, M. S. and WongMui, Y. (2015). Phylogenetic Relationship of Phosphate Solubilizing Bacteria according to 16S rRNA Genes. *Bio - Medical Research International*. http://dx.doi.org/10.1155/2015/201379.

Neni, M., Nuni, G., Abdullah, H. K., Perdana, S. and Abdul, M. R. (2004). Improvement of rice growth and productivity through balance application of inorganic fertilizer and biofertilizer in inceptisol soil of lowland swamp area. *Agrivita*. http://dx.doi.org/10.17503/Agrivita. 36-1-p 048 - 056 36 (1). 1021.

Niño, M. B., Pompe, C. S. C., Edna A. A., Rodrigo, B. B. and Stephan, M. H. (2012). Evaluation of Bio-fertilizers in Irrigated Rice: Effects on Grain Yield at Different Fertilizer. 2 (2012). *Agriculture*, *www.mdpi.com/journal/agriculture*. doi:10.3390/agriculture2010073.

Razzaullah, K., Sher, A., Salimullah, K., Fayaz, A., Meer, Z. and Bashir, A. K. (2002). Effect of different levels of nitrogen, phosphorus and potassium on growth and yield of cabbage. *Asian Journal of Plant Sciences*. Doi: 10.3923/ajps/2002.548.549. Pg. 549.

Roy, R. N., Finck, A., Blair, G. J. and Tandon, H. I. S. (2006). Plant nutrition for food security. A guide for integrated nutrient management. FAO fertilizer and plant nutrition bulletin (16). *Food and Agricultural Organization of the United Nations*, Rome. ISBN 92-5-105490-8. Pg. 25, 52 - 56.

Ruben, A., Garcia, G. and Susan, F. (2015). Standard practice for classification of soil for engineering purpose. *Research Engineering Laboratory*. A unified soil classification system. ERDC/CRREL TR-15 - 4.

Shah, A. and Rajendra, K. S. (2012). Comparative Study on Effect of Chemical and Bio-Fertilizer on Growth, Development and Yield Production of Paddy crop (*Oryza sativa*). *International Journal of Science and Research (IJSR)*. 3(9). Paper ID: SEP147101. 409 and 411.

Staff, K. J. (2018). Fertilizers - Types and their applications https://krishijagran.com/agripedia/fertilizers-types-and-their-applications/

Tinatin, D., Saykal, B. and Maxabat, K. (2015). Effects of Streptomyces Bio-fertilizer to Soil Fertility and Rhizosphere's Functional Biodiversity of Agricultural Plants. *Journal of Advances in Microbiology*. doi.org/10.4236/aim.2015.57058. Pg. 556 - 557 and 568.

Thomas, J. R. (2002). Importance of soil texture to vineyard management. Soil Science Department, California Agriculture.

Vikas G., Manisha, R., Omkar, G. and Babita, K. (2014). Bio-fertilizers - increasing soil fertility and crop productivity. *Jr. of Industrial Pollution Control*. 30 (2).

William, F. B. (2000). Compost quality standards and guidelines. Prepared for New York State Association of Recycles. *Wood End Research Laboratory*, Inc.